Lecture Module - Sensors

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Lecture Module - Sensors

Sensors

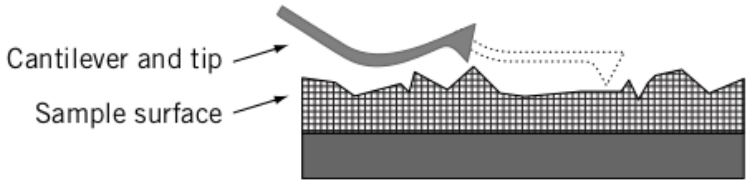
- Topic 1 - Introduction and Overview
- Topic 2 - IC and MEMS based Sensors

Topic 1 - Introduction and Overview

- Analog and Digital Sensors
- Example 1: Distance or Range
- Example 2: Rotation

Analog and Digital Sensors

a sensor, a physical element that employs some natural phenomenon... ...to sense the variable being measured



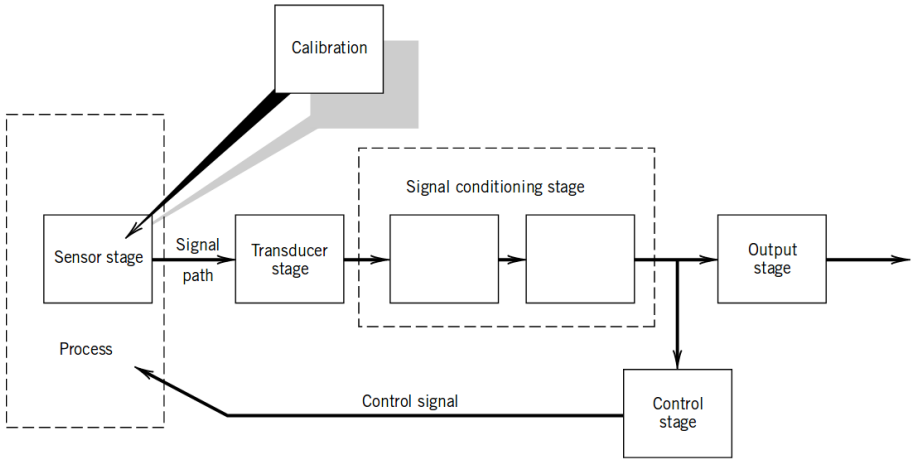


Figure 1.5 Components of a general measurement system.

Image: Theory and Design of Mech. Meas.

Analog and Digital Sensors

Sensors are typically classified as either **analog** or **digital** based on the type of signal that is output from the sensor.

However, this can be a misleading term. Many digital sensors operate based on analog circuit principles but require a digital circuit or MCU to operate or comminicate.

Analog	Digital	Both?

Analog and Digital Sensors

Other Classifications:

- Contact vs Non-Contact
- Programmable (Configurable) vs Non-Programmable
- By Measured Variable

Example 1: Distance or Range

Thought Exercise: How do we measure distance (aka range)?

- What variable or quantity is used to describe distance?
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- What type of sensor is used to measure this?
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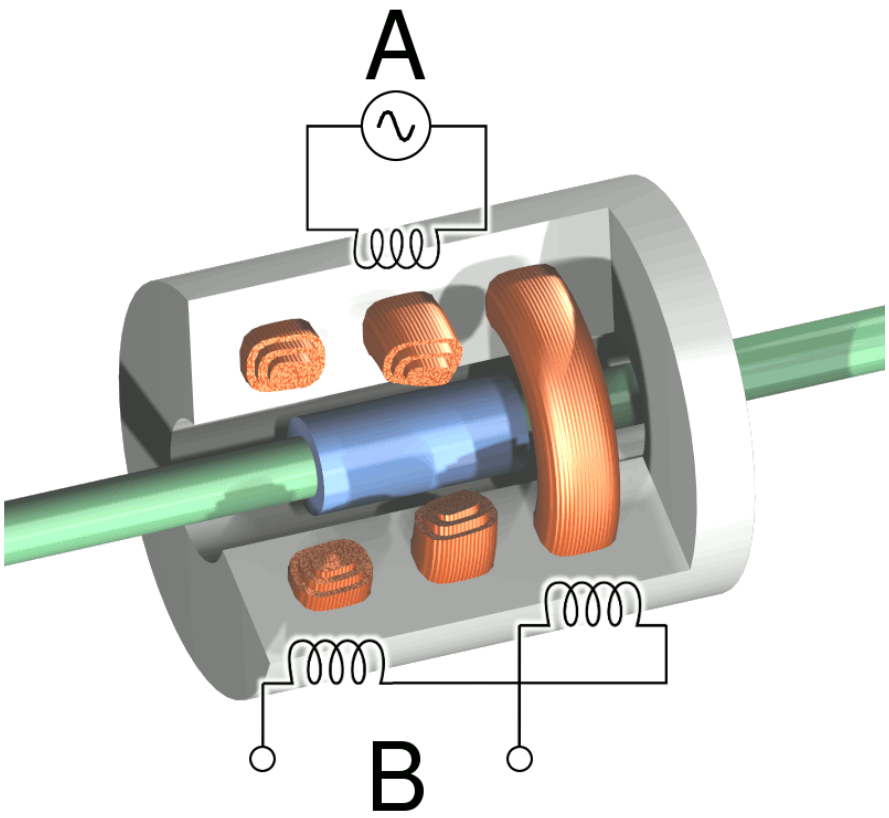
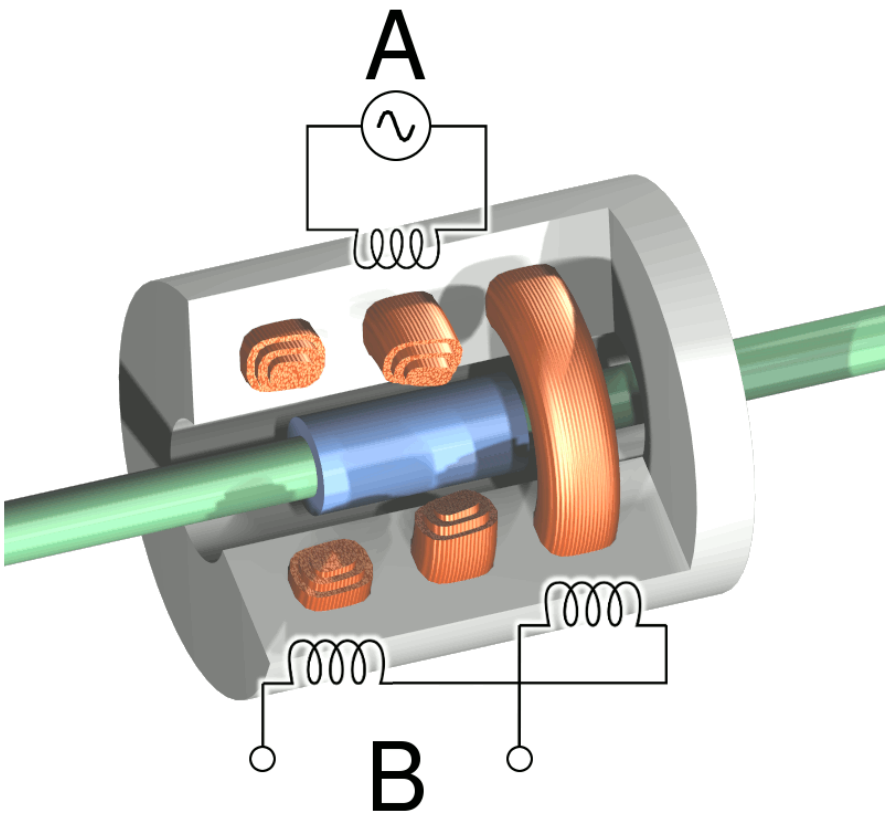
Example 1: Distance or Range



LVDTs with NI
LVDT Animation

Example 1: Distance or Range



Example 1: Distance or Range

- What applications require this type of sensor?
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  -
  -

Example 1: Distance or Range

- How does this type of sensor work?
  -
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Example 2: Rotation

Thought Exercise: How do we measure rotation?

- What variable or quantity is used to describe rotation?
  -
  -
  -
- What type of sensor is used to measure this?
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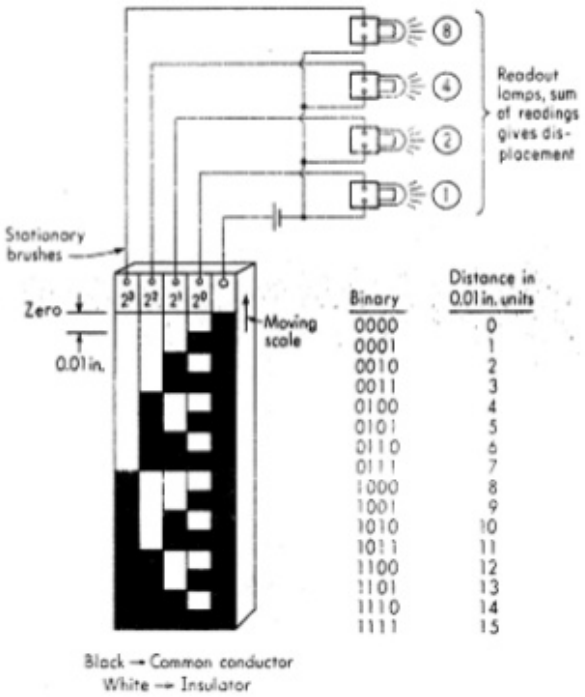
Example 2: Rotation

Rotational Potentiometer

Example 2: Rotation

Absolute Encoder

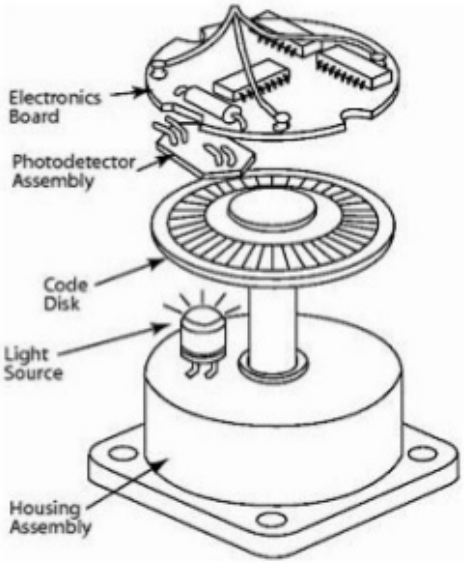
4-Bit Binary Optical Absolute Encoder Disk



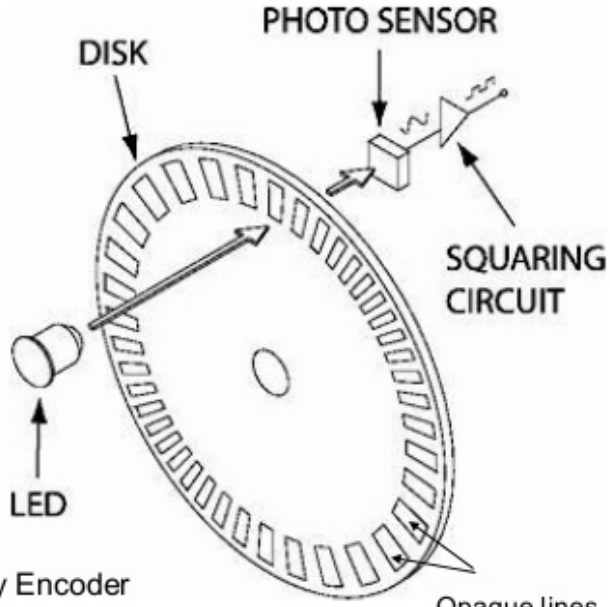
Incremental Encoder

2. Types of Rotary Encoder - Incremental

Construction of Incremental Rotary Encoder



Components inside Incremental Rotary Encoder



Example 2: Rotation

- What applications require this type of sensor?
  -
  -
  -

Example 2: Rotation

- How does this type of sensor work?
  -
  -
  -

Topic 2 - IC and MEMS based Sensors

- Integrated Circuits
- Micro Electro-Mechanical Devices
- Example 1: Accelerometer
- Example 2: Magnometer and Digital Compass

Integrated Circuits

An integrated circuit (also known as an IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece[a] of semiconductor material, usually silicon. Large numbers of miniaturized transistors and other electronic components are integrated together on the chip.

wikipedia: integrated circuit

Integrated Circuits

Actvitity: Group Brainstorming
List three applications or devices that use ICs and or IC based sensors.

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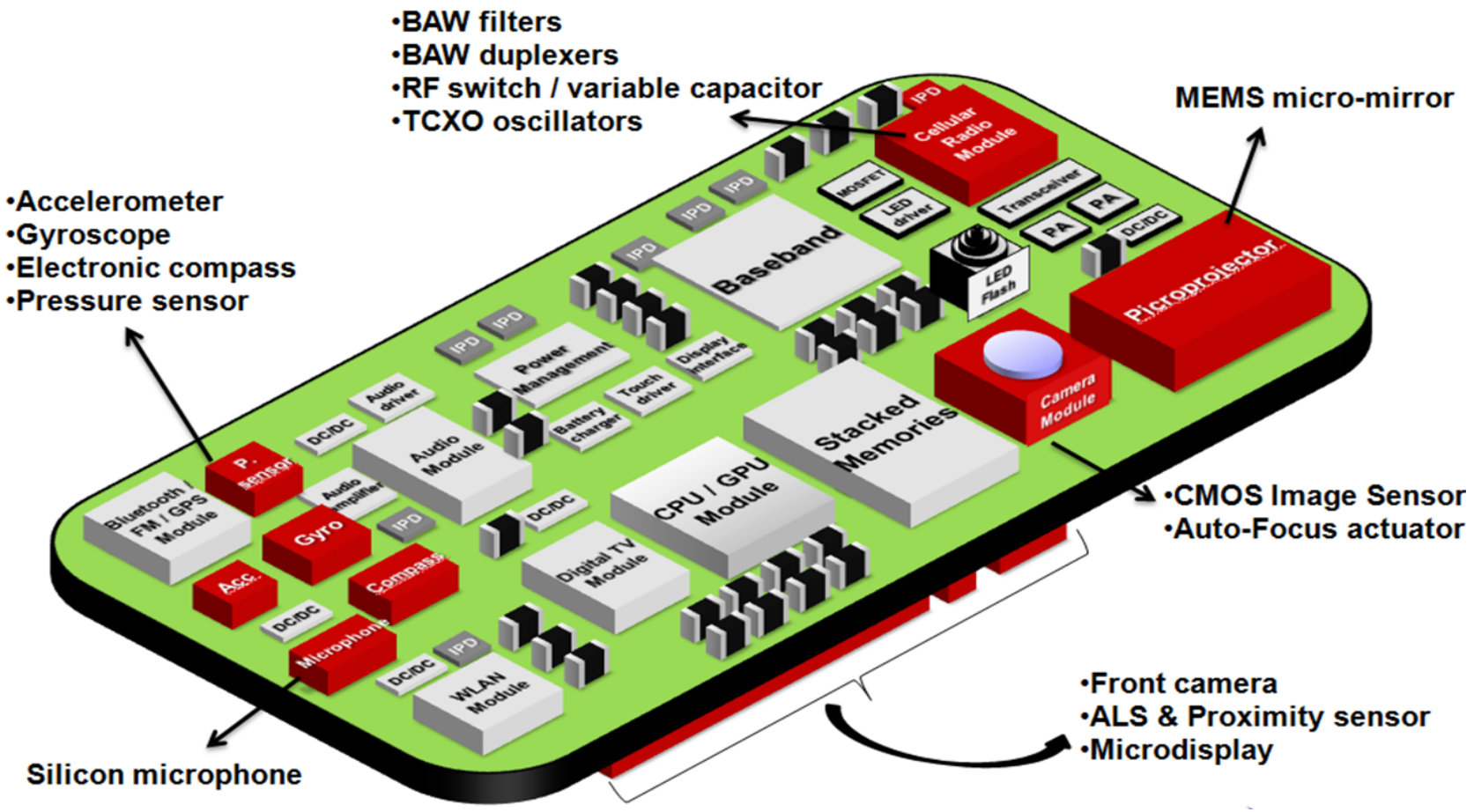
-
-

Integrated Circuits



Micro Electro-Mechanical Devices

MEMS (micro-electromechanical systems) is the technology of microscopic devices incorporating both electronic and moving parts. MEMS are made up of components between 1 and 100 micrometres in size (i.e., 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micrometres to a millimetre (i.e., 0.02 to 1.0 mm), although components arranged in arrays (e.g., digital micromirror devices) can be more than 1000 mm2.[1] They usually consist of a central unit that processes data (an integrated circuit chip such as microprocessor) and several components that interact with the surroundings (such as microsensors)

Wikipedia: MEMS

Micro Electro-Mechanical Devices

Actvitity: Group Brainstorming List three sensors that are found on a high performance quadcopter or drone.

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-
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Example 1: Accelerometer

An accelerometer is a tool that measures proper acceleration, which is the acceleration of a body in its own instantaneous frame.
Applications:

- Navigation Systems - Robotics - Aircraft - Missiles
- Personal Devices - Phones - Tablets
- Others:

Example 1: Accelerometer

Thought Exercise: How do we measure acceleration?

Actvitity: Group Brainstorming
Explain one method for measuring acceleration of a body.

Example 1: Accelerometer

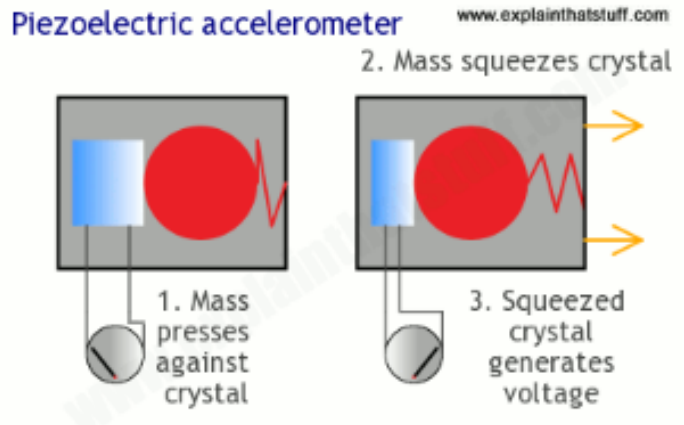
Mechanical Accelerometers Consist of a damped mass spring system and a sensing device.
Types of accelerometers:

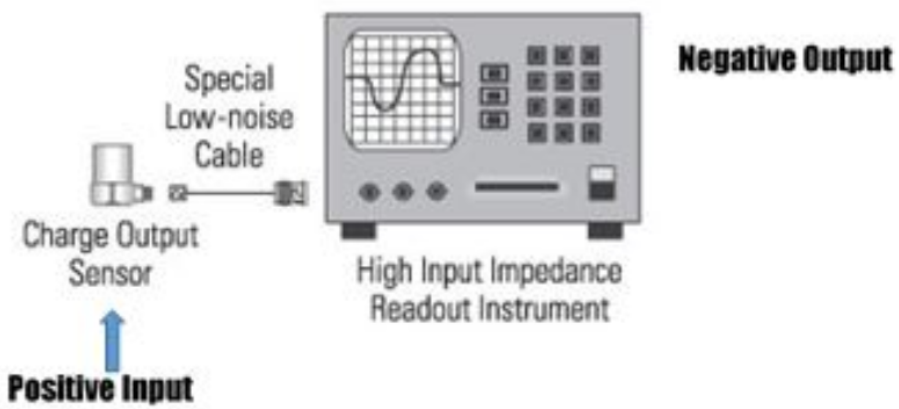
- Seismometer or Seismograph
- Piezoelectric - charge in material resulting from mechanical stress
- Piezoresistive - change in resistance resulting from mechanical stress
- Capacitive
- Multi Axis - triaxial

Accelerometer Types - Omega

Example 1: Accelerometer

Piezoelectric accelerometer (charge mode)





Example 1: Accelerometer

Peizoelectronic accelerometer with embedded amplifier circuit (ICP)

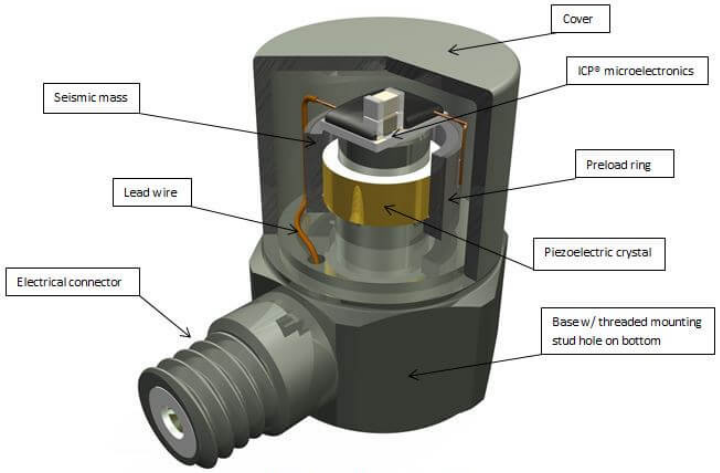
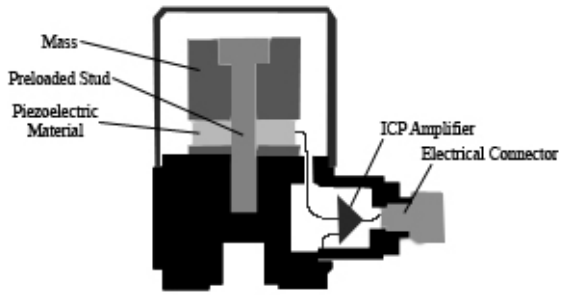
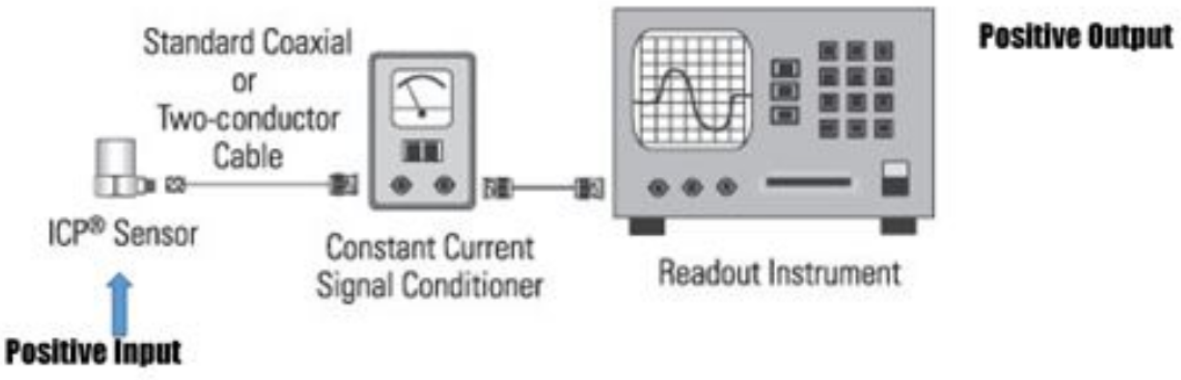


Figure 1: Typical ICP® Accelerometer

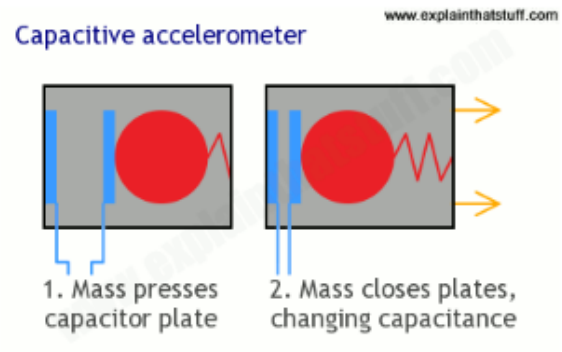




ICP Accelerometers - PCB Peizotronics

Example 1: Accelerometer

Capacitive accelerometer



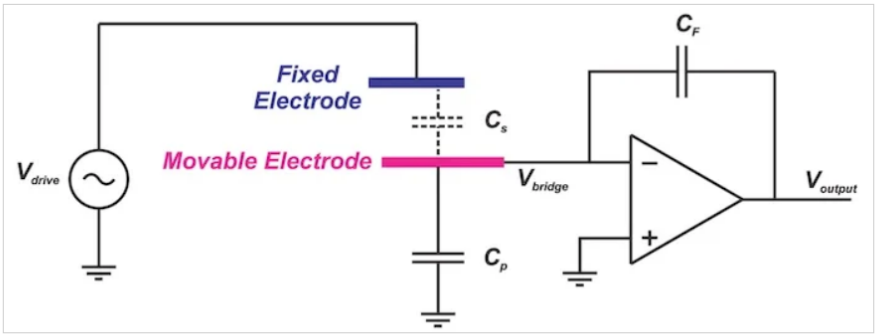


Figure 5

$$V_{output} = -\frac{C_s}{C_F} V_{drive}$$

$$C = \epsilon \frac{A}{d}$$

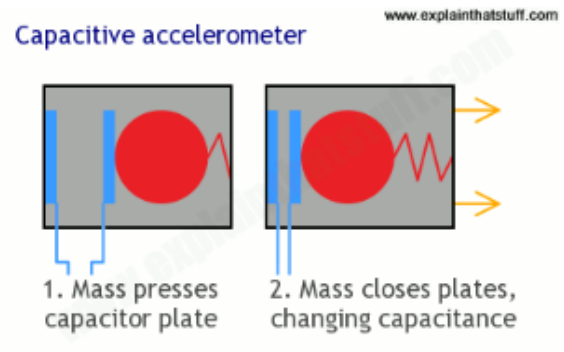
$$V_{output} = -\frac{d_F}{d_s} V_{drive}$$

$$V_{output} = \frac{d_F}{d_0 + \Delta d} V_{drive}$$

Capacitive Accelerometers - All About Circuits

Example 1: Accelerometer

Capacitive accelerometer



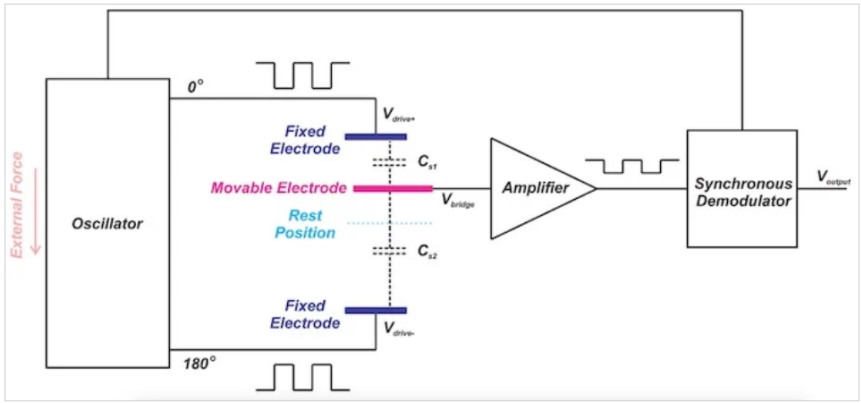


Figure 4. *Image (adapted) courtesy of Analog Devices*

$$V_{bridge} = \frac{C_{s1} V_{drive+} + C_{s2} V_{drive-}}{C_{s1} + C_{s2}}$$

$$V_{bridge} = \frac{d_{s2} V_{drive+} + d_{s1} V_{drive-}}{d_{s1} + d_{s2}}$$

$$d_{s1} = d_0 - \Delta d$$

$$d_{s2} = d_0 + \Delta d$$

$$V_{drive+} = -V_{drive-}$$

$$V_{bridge} = \frac{\Delta d}{d_0} V_{drive+}$$

capacitive accelerometer wiring Position and motion sensors

Example 2: Magnometer and Digital Compass

Thought Exercise: How do we measure orientation?

- What variable or quantity is used to describe motion?
  -
  -
  -
- What type of sensor is used to measure this?
  -
  -
  -

Example 2: Magnometer and Digital Compass

- What applications require this type of sensor?
  -
  -
  -

Example 2: Magnometer and Digital Compass

A magnetometer is a device that measures magnetic field or magnetic dipole moment. Different types of magnetometers measure the direction, strength, or relative change of a magnetic field at a particular location. A compass is one such device, one that measures the direction of an ambient magnetic field, in this case, the Earth's magnetic field. Other magnetometers measure the magnetic dipole moment of a magnetic material such as a ferromagnet, for example by recording the effect of this magnetic dipole on the induced current in a coil.

wikipedia: magnetometer